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Patents ADP number (*if you know it*):

If the applicant is a corporate body, give the United Kingdom (GB) country/state of its incorporation:

8333072003

3. Title of the invention: "An Improved Mist Generating Apparatus and Method"

4. Name of your agent (*if you have one*): Murgitroyd & Company

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Date: 15 September 2006

12. Name, e-mail address, telephone, fax and/or mobile number, if any, of a contact point for the applicant:

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An Improved Mist Generating Apparatus and Method

1 The present invention relates to the field of mist
2 generating apparatus. More specifically, the
3 invention is directed to an improved apparatus and
4 method for generating liquid droplet mists.

5

6 Mist generating apparatus are known and are used in
7 a number of fields. For example, such apparatus are
8 used in both fire suppression and cooling
9 applications, where the liquid droplet mists
10 generated are more effective than a conventional
11 fluid stream. Examples of such mist generating
12 apparatus can be found in WO2005/082545 and
13 WO2005/082546 to the same applicant.

14

15 A problem with conventional mist generating
16 apparatus is that not all of the working fluid being
17 used is atomised as it passes through the apparatus.
18 Although the majority of the working fluid is
19 atomised upon entry into the mixing chamber of the
20 apparatus, some fluid is pulled into the chamber but

1 is not atomised. The non-atomised fluid can stick
2 to the wall of the mixing chamber and flow
3 downstream along the wall to the outlet nozzle,
4 where it can fall into the atomised fluid stream.
5 This can cause the creation of droplets which are of
6 non-uniform size. These droplets can then coalesce
7 with other droplets to create still larger droplets,
8 thus increasing the problem and creating a mist of
9 non-uniform droplets.

10

11 In cooling applications in particular, the
12 uniformity of the size of the droplets in the mist
13 is important. In turbine cooling applications, for
14 example, droplets which are over $10\mu\text{m}$ in diameter
15 can cause significant damage to the turbine blades.
16 It is therefore important to ensure control and
17 uniformity of droplet size. Optimally sized
18 droplets will evaporate, thus absorbing heat energy
19 and increasing the air density in the turbine. This
20 ensures that the efficiency of the turbine is
21 improved. Existing turbine cooling systems employ
22 large droplet eliminators to remove large droplets
23 and thus prevent damage to the turbine. However,
24 such eliminators add to the complexity and
25 manufacturing cost of the apparatus.

26

27 It is an aim of the present invention to obviate or
28 mitigate one or more of the aforementioned
29 disadvantages.

30

1 According to a first aspect of the present invention
2 there is provided an apparatus for generating a
3 mist, comprising:
4 a generally cylindrical body; and
5 an elongate member co-axially located within
6 the body such that a first transport fluid passage
7 and a nozzle are defined between the body and the
8 elongate member, the first transport fluid passage
9 having a convergent-divergent internal geometry and
10 being in fluid communication with the nozzle;
11 wherein the elongate member includes a working
12 fluid passage and one or more communicating bores
13 extending radially outwardly from the working fluid
14 passage, the bores allowing fluid communication
15 between the working fluid passage and the first
16 transport fluid passage; and
17 wherein the one or more communicating bores are
18 substantially perpendicular to the first transport
19 fluid passage.
20
21 Preferably, the communicating bore has an inlet
22 connected to the working fluid passage and an outlet
23 connected to the working fluid passage, the outlet
24 having a greater cross-sectional area than the
25 inlet.
26
27 The body has an internal wall having an upstream
28 convergent portion and a downstream divergent
29 portion, the convergent and divergent portions at
30 least in part forming the convergent-divergent
31 internal geometry of the first working fluid
32 passage. A first end of the elongate member has a

1 cone-shaped projection, wherein the nozzle is
2 defined between the divergent portion of the
3 internal wall and the cone-shaped projection. The
4 one or more communicating bores are adjacent the
5 first end of the elongate member.

6

7 Preferably, the cone-shaped projection has a ramped
8 portion extending upwardly from the surface thereof.

9

10 In a first preferred embodiment, the elongate member
11 further includes a second transport fluid passage
12 having an outlet adjacent the end of the cone-shaped
13 projection. Preferably, the first and second
14 transport fluid passages are substantially parallel.
15 The second transport fluid passage preferably
16 includes an expansion chamber adjacent its outlet.

17

18 In a second preferred embodiment, the bores allowing
19 communication between the working fluid passage and
20 the first transport fluid passage are first bores,
21 and the body further includes a second working fluid
22 passage and one or more second communicating bores
23 allowing fluid communication between the second
24 working fluid passage and the first transport fluid
25 passage. Preferably, the second working fluid
26 passage circumscribes the first working fluid
27 passage and the first transport fluid passage.
28 Preferably, the second bores are substantially
29 perpendicular to the first transport fluid passage.
30 Most preferably, the first and second bores are co-
31 axial.

32

1 In a third preferred embodiment, the elongate member
2 further includes:

3 a second transport fluid passage circumscribing
4 the working fluid passage;

5 one or more first communicating bores extending
6 radially outwardly from the working fluid passage,
7 the first bores allowing fluid communication between
8 the working fluid passage and the second transport
9 fluid passage; and

10 one or more second communicating bores
11 extending radially outwardly from the second
12 transport fluid passage, the second bores allowing
13 fluid communication between the second transport
14 fluid passage and the first transport fluid passage;
15 wherein the first and second communicating
16 bores are substantially perpendicular to the second
17 and first transport fluid passages, respectively.

18
19 Preferably, the elongate member further includes a
20 third transport fluid passage adapted to supply
21 transport fluid into the second transport fluid
22 passage adjacent the first and second communicating
23 bores.

24
25 Alternatively, the first transport fluid passage
26 communicates with the nozzle via an outlet and a
27 second transport fluid passage in fluid
28 communication with the outlet, wherein the second
29 transport fluid passage has a convergent-divergent
30 internal geometry and is substantially perpendicular
31 to the first transport fluid passage.

32

1 As a further alternative, the apparatus further
2 comprises a mixing chamber located between the first
3 transport fluid passage and the nozzle, and a second
4 transport fluid passage in communication with the
5 mixing chamber and the first transport fluid
6 passage, wherein the second transport fluid passage
7 is adapted to supply transport fluid to the mixing
8 chamber in a direction of flow substantially opposed
9 to a direction of flow of transport fluid from the
10 first transport fluid passage.

11

12 According to a second aspect of the invention, there
13 is provided a method of generating a mist, the
14 method comprising the steps of:

15 supplying a working fluid through a working
16 fluid passage;

17 supplying a first transport fluid through a
18 first transport fluid passage;

19 forcing the working fluid from the working
20 fluid passage into the first transport fluid passage
21 via one or more communicating bores extending
22 radially outwardly from the working fluid passage;

23 accelerating the first transport fluid upstream
24 of the communicating bores so as to provide a high
25 velocity transport fluid flow; and

26 applying the high velocity transport fluid flow
27 to the working fluid exiting the communicating
28 bores, thereby imparting a shear force on the
29 working fluid and atomising the working fluid to
30 produce a dispersed droplet flow regime;

1 wherein the high velocity transport fluid flow
2 is applied substantially perpendicular to the
3 working fluid flow exiting the bores.

4

5 Preferably, the method further includes the steps
6 of:

7 forcing the atomised working fluid from the
8 first transport fluid passage into a second
9 transport fluid passage via one or more second
10 communicating bores extending radially outwardly
11 from the first transport fluid passage;

12 supplying a second transport fluid through the
13 second transport fluid passage;

14 accelerating the second transport fluid
15 upstream of the second communicating bores so as to
16 provide a second high velocity transport fluid flow;
17 and

18 applying the second high velocity transport
19 fluid flow to the atomised working fluid exiting the
20 second communicating bores, thereby imparting a
21 second shear force on the atomised working fluid and
22 further atomising the working fluid;

23 wherein the second high velocity transport
24 fluid flow is applied substantially perpendicular to
25 the atomised working fluid flow exiting the second
26 bores.

27

28 Preferred embodiments of the present invention will
29 be described, by way of example only, with reference
30 to the accompanying drawings, in which:

31

1 Figures 1(a)-1(e) show detail section views
2 through a first embodiment of a mist generating
3 apparatus;

4 Figure 2 shows a detail section view through a
5 second embodiment of a mist generating apparatus;

6 Figure 3 shows a section view through a third
7 embodiment of a mist generating apparatus;

8 Figures 4(a)-4(c) show detail section views
9 through a fourth embodiment of a mist generating
10 apparatus;

11 Figure 5 shows a detail section view through a
12 fifth embodiment of a mist generating apparatus;

13 Figure 6 shows a detail section view through a
14 sixth embodiment of a mist generating apparatus; and

15 Figure 7 shows a detail section view through a
16 seventh embodiment of a mist generating apparatus.

17
18 Figure 1(a) shows a first embodiment of mist
19 generating apparatus according to the present
20 invention. The apparatus, generally designated 10,
21 comprises a generally cylindrical body 12 and an
22 elongate member 14 projecting co-axially within the
23 body 12. The member 14 and body 12 are so arranged
24 that a first transport fluid passage 16 and a nozzle
25 32 are defined between the two. The body 12 has an
26 internal wall 18 which includes a convergent portion
27 20 upstream of a divergent portion 22. The elongate
28 member 14 has an external wall 24 which is
29 substantially straight and parallel to the
30 longitudinal axis L shared by the body and elongate
31 member. As Figure 1(a) is only a detail view, it
32 will be appreciated that the entire apparatus is not

1 illustrated in this figure. As the body 12 is
2 generally cylindrical, a further portion of the body
3 12, mirrored about the longitudinal axis L, is
4 present below the elongate member 14, but is not
5 shown in Figure 1(a) for reasons of clarity. Thus,
6 passage 16 is an annular passage surrounding the
7 elongate member 14. The elongate member 14 ends in
8 a cone-shaped projection 15.

9

10 The elongate member 14 includes a passage 26 for the
11 introduction of a working fluid. The passage will
12 therefore be referred to as the working fluid
13 passage 26. The passage 26 extends along the length
14 of the elongate member 14 and is also co-axial with
15 the body 12 and elongate member 14. The passage 26
16 is blind, in that it ends in a cavity 28 located in
17 the outer cone portion 15 of the elongate member 14.
18 Extending radially outwardly from the passage 26 in
19 a direction substantially perpendicular to the
20 transport fluid passage 16 are one or more
21 communicating bores 30. These bores 30 allow fluid
22 communication between the working fluid passage 26
23 and the transport fluid passage 16. The outer cone
24 portion 15 of the elongate member 14 and the
25 divergent portion 22 of the internal wall 18 define
26 a mixing chamber 19 which opens out into a nozzle 32
27 through which fluid is sprayed.

28

29 The operation of the first embodiment will now be
30 described. A working fluid, such as water for
31 example, is introduced from a working fluid inlet
32 (not shown) into the working fluid passage 26. The

1 working fluid flows along the passage 26 until
2 reaching the cavity 28. Upon reaching the cavity
3 28, the working fluid is forced through the bores 30
4 into the transport fluid passage 16. A transport
5 fluid, such as steam for example, is introduced from
6 a transport fluid inlet (not shown) into the
7 transport fluid passage 16. Due to the convergent-
8 divergent section of the passage 16 formed by the
9 convergent and divergent portions 20,22 of the body
10 18, the passage acts as a venturi section,
11 accelerating the transport fluid as it passes
12 through the convergent-divergent section into the
13 mixing chamber 19. This acceleration of the
14 transport fluid ensures that the transport fluid
15 flows past the ends of the bores 30 at very high,
16 possibly even supersonic, velocity.

17
18 With the transport fluid flowing at such high
19 velocity and the working fluid exiting the bores 30
20 into the passage 16 in a direction substantially
21 perpendicular to the transport fluid flow, the
22 working fluid is subjected to very high shear forces
23 by the transport fluid. Droplets are sheared from
24 the working fluid flow as it exits the bores 30
25 producing a dispersed droplet flow regime. The
26 atomised flow is then carried out through the mixing
27 chamber 19 to the nozzle 32. In such a manner, the
28 apparatus 10 creates a flow of substantially uniform
29 sized droplets from the working fluid.

30
31 Figures 1(b)-1(e) show potential modifications to
32 the nozzle 32 adjacent the outlet of the bores 30:

1 Figures 1(b) -1(d) show nozzles where the outlet of
2 the bore 30 has a greater cross-sectional area than
3 the inlet 29 communicating with the working fluid
4 passage 26. In Figure 1(b) the bore 30 has a curved
5 outward taper at the outlet 31b which provides the
6 outlet 31b with a bowl-shaped profile when viewed in
7 section. In Figure 1(c), a similar arrangement is
8 shown, but here the expanded diameter of the outlet
9 31c is achieved by providing a stepped portion
10 rather than a gradual outward taper. With the
11 nozzle of Figure 1(d), the bore 30 gradually tapers
12 outwards along the length thereof from inlet 29 to
13 outlet 31d.

14

15 By providing bores 30 whose outlets 31b,31c,31d are
16 of greater diameter than their respective inlets 29,
17 an area of lower pressure is provided in the working
18 fluid as it leaves the outlets 31b,31c,31d. This
19 has the effect of presenting a greater surface area
20 of working fluid to the transport fluid in the
21 mixing chamber 19, thereby further increasing the
22 shear effect of the transport fluid on the working
23 fluid. Additionally, the expansion of the bores 30,
24 particularly in the cases of the Figure 1(b) and
25 1(c) nozzles, will increase the turbulence of the
26 working fluid flow as it exits the bores 30,
27 limiting the potential for any of the working fluid
28 flow to become trapped along the walls of the bores
29 30.

30

31 As explained above, one undesirable phenomenon in
32 mist generating apparatus is that some of the

1 working fluid is not instantly atomised upon exit
2 from the bores 30. In such instances, the non-
3 atomised fluid can flow along the wall of the outer
4 cone portion 15 of the nozzle 32 and then disrupt
5 the size of the working fluid droplets which have
6 already been atomised. This phenomenon can be
7 avoided in the nozzle shown in Figure 1(e). With
8 this nozzle, the wall of the outer cone portion 15
9 is provided with a ramped portion 34 which extends
10 upwardly from the outer cone wall to a peak, also
11 known as a surface separation point. Any non-
12 atomised fluid flow along the outer cone 15 will
13 flow up the ramped portion 34. Once the fluid flow
14 arrives at the peak, it will be subjected to the
15 shear forces of the transport fluid, will atomise,
16 and then join the remainder of the droplets as they
17 exit the nozzle 32.

18
19 Figure 2 shows a second embodiment of the apparatus,
20 which also solves the same problem as the modified
21 nozzle of Figure 1(e). In this instance, the
22 elongate member 14 includes a working fluid passage
23 26 as before. However, instead of passing through
24 the central axis of the elongate member 14 as in the
25 previously described embodiments, in this embodiment
26 the working fluid passage 26 is arranged so as to
27 circumscribe a second transport fluid passage 40
28 located along the longitudinal axis of the elongate
29 member 14. The purpose of the second transport
30 fluid passage 40 is to ensure any non-atomised fluid
31 which flows down the surface of the outer cone 15 is
32 atomised when it reaches the outlet 42 of the

1 passage 40, which is adjacent the end of the outer
2 cone 15. Thus, transport fluid flows through both
3 the first transport fluid passage 16 and the second
4 transport fluid passage 40. The second transport
5 fluid passage 40 can include an expansion chamber 44
6 if desired, and is preferably substantially parallel
7 to the first transport fluid passage 16.

8

9 A third embodiment of the apparatus is shown in
10 Figure 3. This embodiment shares a number of
11 features with the first embodiment described above.
12 As a result, these features will not be described
13 again in detail here, but have been assigned the
14 same reference numbers, where appropriate. The
15 first difference between the first and third
16 embodiments is that the external wall 24' of the
17 elongate member 14 is of the same convergent-
18 divergent geometry as the internal wall 18 of the
19 body 12. Hence, the convergent and divergent
20 portions 20,22 of the internal wall 18 are mirrored
21 by identical portions of the external wall 24' of
22 the elongate member 14. As a result, both walls
23 18,24' define a throat section 50 in the first
24 transport fluid passage 16.

25

26 The second key difference between the third
27 embodiment of the apparatus and the preceding
28 embodiments is that as well as having a first
29 working fluid passage 26 along the centre of the
30 elongate member 14, a second working fluid passage
31 52 is also provided in the body 12, the second
32 working fluid passage 52 circumscribing both the

1 first working fluid passage 26 and the transport
2 fluid passage 16. This means that working fluid is
3 supplied into the mixing chamber 19 from both first
4 and second bores 30,54 which extend radially
5 outwardly from their respective passages 26,52 and
6 connect the first and second working fluid passages
7 26,52 with the transport fluid passage 16. As with
8 the first working fluid passage 26, the second
9 working fluid passage 52 is also blind, with a
10 cavity 56 located at the end of the passage 52
11 remote from the working fluid inlet (not shown).
12 The first and second bores 30,54 are preferably co-
13 axial, as seen in section in Figure 3. This ensures
14 that the working fluid enters the transport fluid
15 passage 16 at the same point from both the first and
16 second working fluid passages 26,52. The first and
17 second bores 30,54 are substantially perpendicular
18 to the transport fluid passage 16.

19

20 The third embodiment will operate in substantially
21 the same manner as that described in respect of the
22 first embodiment. Working fluid exiting the first
23 and second bores 30,54 will be sheared by the
24 transport fluid flowing through the transport fluid
25 passage 16, thereby creating a mist of uniform sized
26 droplets.

27

28 A fourth embodiment of the invention is illustrated
29 in Figure 4(a). Again, the basic layout of the
30 apparatus is the same as with the first embodiment,
31 so like features have been again assigned the same
32 reference numbers. The elongate member 14 has a

1 central working fluid passage 26 which ends in a
2 cavity 28 remote from a working fluid inlet (not
3 shown). A first transport fluid passage 16 is
4 defined by an external wall 24 of the elongate
5 member 14 and convergent and divergent portions
6 20,22 of the internal wall 18 of the body 12.
7 Again, it will be appreciated that Figure 4(a) only
8 illustrates half of the apparatus, with the half not
9 illustrated being a mirror image about the
10 longitudinal axis L of the illustrated portion.

11

12 The elongate member 14 of this fourth embodiment is
13 adapted to include a second transport fluid passage
14 60 circumscribing the central working fluid passage
15 26. The transport and working fluid passages 60,26
16 are co-axial about the longitudinal axis L. With
17 the second transport fluid passage 60 circumscribing
18 the working fluid passage 26, the second transport
19 fluid passage lies between the working fluid passage
20 26 and the first transport fluid passage 16. A
21 number of first bores 62 allow fluid communication
22 between the working fluid passage 26 and the second
23 transport fluid passage 60. A number of second
24 bores 64 allow fluid communication between the
25 second transport fluid passage 60 and the first
26 transport fluid passage 16.

27

28 In operation, working fluid is forced through the
29 first bores 62 into the second transport fluid
30 passage 60, where transport fluid shears the working
31 fluid entering the passage perpendicular to the
32 transport fluid flow. The resultant atomised fluid

1 then flows through the second bores 64 into the
2 first transport fluid passage 16, whereupon it is
3 sheared for a second time by a second flow of
4 transport fluid. Providing two locations at which
5 the working fluid is subjected to the shear forces
6 of the transport fluid allows the apparatus to
7 generate still smaller droplet sizes.

8

9 Figures 4(b) and 4(c) illustrate examples of
10 communicating bores 70,72 which are not
11 perpendicular to the flow of transport fluid through
12 the transport fluid passage 16. The bore 70 of
13 Figure 4(b) presents fluid into the transport fluid
14 flow at an angle of less than 90 degrees such that
15 the fluid flows against the flow of transport fluid.
16 Such an arrangement increases the shear forces on
17 the working fluid from the transport fluid. In
18 Figure 4(c) the bore 72 is at an angle of over 90
19 degrees, so that the fluid flow is at an angle to
20 the transport fluid flow, but is not perpendicular
21 thereto. This arrangement reduces the amount of
22 shear imparted on the working fluid by the transport
23 fluid.

24

25 A fifth embodiment of the invention is illustrated
26 in Figure 5. The elongate member 14 has a central
27 working fluid passage 26 which ends in a cavity 28
28 remote from a working fluid inlet (not shown). A
29 first transport fluid passage 16 is defined by an
30 external wall 24 of the elongate member 14 and
31 convergent and divergent portions 20,22 of the
32 internal wall 18 of the body 12. In this

1 embodiment, the external wall 24 of the elongate
2 member 14 tapers outwardly in the direction of the
3 mixing chamber 19 and nozzle 32 until it reaches one
4 or more second bores 64. Again, it will be
5 appreciated that Figure 5 only illustrates half of
6 the apparatus, with the half not illustrated being a
7 mirror image about the longitudinal axis L of the
8 illustrated portion.

9

10 The elongate member 14 of this fourth embodiment is
11 adapted to include a second transport fluid passage
12 60 circumscribing the central working fluid passage
13 26. The transport and working fluid passages 60,26
14 are co-axial about the longitudinal axis L. With
15 the second transport fluid passage 60 circumscribing
16 the working fluid passage 26, the second transport
17 fluid passage lies between the working fluid passage
18 26 and the first transport fluid passage 16. One or
19 more first bores 62 allow fluid communication
20 between the working fluid passage 26 and the second
21 transport fluid passage 60. One or more of the
22 second bores 64 allow fluid communication between
23 the second transport fluid passage 60 and the first
24 transport fluid passage 16.

25

26 A further difference between the fifth embodiment
27 and the preceding fourth embodiment in particular is
28 that a third transport fluid passage 80 is provided
29 in the elongate member 14. The third transport
30 fluid passage 80 may receive transport fluid from
31 the same source as the first and second transport
32 fluid passages 16,60, or else it may have its own

1 dedicated transport fluid source (not shown). The
2 third transport fluid passage 80 has an outlet 82
3 which is on the downstream side of the first bore(s)
4 62. As a result, the outlets of the second and
5 third transport fluid passages 60,80 are positioned
6 either side of the first bores 62 and open into the
7 second bores 64.

8

9 In operation, working fluid is forced through the
10 first bores 62 from the working fluid passage 26,
11 where transport fluid from the second and third
12 transport fluid passages 60,80 shears the working
13 fluid. The resultant atomised fluid then flows
14 through the second bores 64 into the first transport
15 fluid passage 16, whereupon it is sheared for a
16 second time by a second flow of transport fluid.
17 Providing two locations at which the working fluid
18 is subjected to the shear forces of the transport
19 fluid allows the apparatus to generate still smaller
20 droplet sizes. By providing two sources of
21 transport fluid from the second and third transport
22 fluid passages 60,80 adjacent the first bore(s) 62,
23 even smaller droplets of the working fluid can be
24 obtained due to the effective twin shear action of
25 the transport fluid on the working fluid prior to
26 the atomised fluid entering the second bore(s) 64
27 and being further atomised.

28

29 Figures 6 and 7 show sixth and seventh embodiments
30 of the apparatus, respectively, in which secondary
31 shear actions take place in the manner of the fourth
32 and fifth embodiments described above. In the sixth

1 embodiment shown in Figure 6, the elongate member 14
2 has a central working fluid passage 26 which ends in
3 a cavity 28 remote from a working fluid inlet (not
4 shown). A first transport fluid passage 16 is
5 defined by an external wall 24 of the elongate
6 member 14 and convergent and divergent portions
7 20,22 of the internal wall 18 of the body 12. The
8 external wall 24 of the elongate member 14 runs
9 substantially parallel to the transport fluid
10 passage 26. One or more first bores 62 allow fluid
11 communication between the working fluid passage 26
12 and the first transport fluid passage 16.

13

14 The key difference between the sixth embodiment and
15 the fifth embodiment in particular is that a second
16 transport fluid passage 90 is provided, but in this
17 case the second transport fluid passage 90 is
18 substantially perpendicular to the first transport
19 fluid passage 16. The second transport fluid
20 passage 90 may receive transport fluid from the same
21 source as the first transport fluid passage 16, or
22 else it may have its own dedicated transport fluid
23 source (not shown). In this embodiment, the first
24 transport fluid passage 16 has an outlet 17 in
25 communication with the second transport fluid
26 passage 90. A mixing chamber 19 is defined where
27 the first and second transport fluid passages 16,90
28 meet one another. The second transport fluid
29 passage 90 has a convergent-divergent internal
30 geometry upstream of the first transport fluid
31 passage outlet 17, thereby ensuring that the
32 transport fluid passing through the passage 90 is

20

1 accelerated prior to meeting the atomised fluid
2 exiting the first transport fluid passage 16.

3

4 In operation, working fluid is forced through the
5 first bores 62 from the working fluid passage 26,
6 where transport fluid from the first transport fluid
7 passage 16 shears the working fluid. The resultant
8 atomised fluid then flows through the outlet 17 into
9 the second transport fluid passage 90, whereupon it
10 is sheared for a second time by the second flow of
11 transport fluid.

12

13 The seventh embodiment of the invention differs from
14 the sixth embodiment in that the second transport
15 fluid passage 100 is arranged such that the
16 direction of the second transport fluid flow is
17 generally opposite to the flow of transport fluid
18 through the first transport fluid passage 16. As
19 before, both the first and second transport fluid
20 passages 16,100 have convergent-divergent internal
21 geometry.

22

23 Working fluid exits the working fluid passage 26 via
24 first bore(s) 62 in a flow direction perpendicular
25 to the first transport fluid passage 16. Transport
26 fluid accelerated through the passage 16 shears the
27 working fluid exiting the bore(s) 62, creating an
28 atomised fluid flow. The atomised fluid flow,
29 flowing in the direction indicated by arrow D1, then
30 meets the accelerated secondary transport fluid
31 flow, illustrated by arrow D2, at a mixing chamber
32 19. The two fluid flows D1,D2 combine in the mixing

21

1 chamber 19 to further atomise the working fluid
2 prior to the atomised working fluid exiting via
3 outlet 104.

4

5 The purpose of the sixth and seventh embodiments is
6 to shear the working fluid once and then carry the
7 droplets into a further stream of transport fluid
8 where the velocity of the droplets is reduced. This
9 allows the production of uniform droplets by
10 shearing with a first, preferably supersonic, stream
11 of transport fluid and then reducing the velocity of
12 the stream with the second transport fluid flow.
13 These embodiments are for use in applications which
14 require small droplet size but low projection
15 velocities.

16

17 Each of the embodiments described here uses the
18 generally perpendicular arrangement of the working
19 fluid bores and transport fluid passages to obtain a
20 crossflow of the transport and working fluids. This
21 crossflow (where the two fluid flows meet at
22 approximately 90 degrees to one another) ensures the
23 penetrative atomisation of the working fluid as the
24 transport fluid breaks up the working fluid. The
25 natural Kelvin-Helmholtz/Rayleigh Taylor
26 instabilities in the working fluid as it is forced
27 into an ambient pressure environment also assist the
28 atomisation of the working fluid.

29

30 Furthermore, by locating the elongate member 14
31 along the centre of the apparatus, the atomised
32 working fluid exits the apparatus via an annular

1 nozzle which circumscribes the elongate member. The
2 elongate member effectively blocks the centre of the
3 nozzle, which provides a further geometric mechanism
4 to assist the atomisation of the working fluid. The
5 blocking of the centre of the nozzle creates a low
6 pressure recirculation zone adjacent the nozzle cone
7 15. As the high-speed atomised working fluid exits
8 the annular nozzle it imparts further shear forces
9 on the droplets in the recirculation zone, leading
10 to a further atomisation of the working fluid.

11

12 In the fifth embodiment shown in Figure 5, the
13 method of operation may be adapted by swapping the
14 functions of the fluid passages 26,60,80. In other
15 words, the passage 26 could supply the transport
16 fluid, whilst the passages 60,80 supply the working
17 fluid. In an alternative adaptation of the
18 apparatus of the fifth embodiment, the apparatus
19 could be adapted to feed gas bubbles through the
20 first bores 62 as the working fluid passes through.
21 This has the effect of breaking up the working fluid
22 stream prior to atomisation and also increasing
23 turbulence in the working fluid, both of which help
24 improve the atomisation of the working fluid in the
25 apparatus.

26

27 Further modifications and improvements may be
28 incorporated without departing from the scope of the
29 invention.

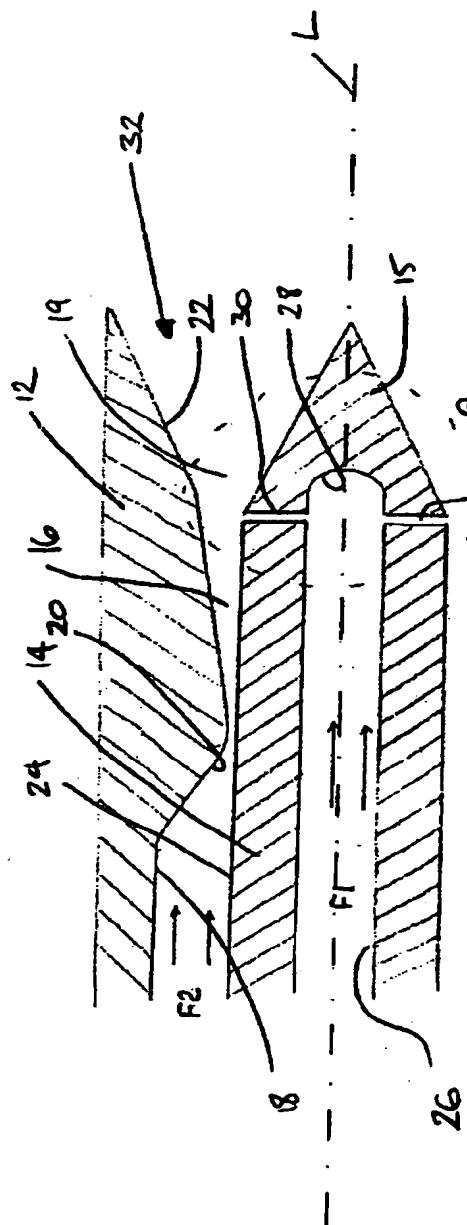


Fig. 1(a)

31b

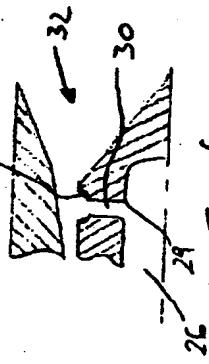


Fig. 1(b)



Fig. 1(c)

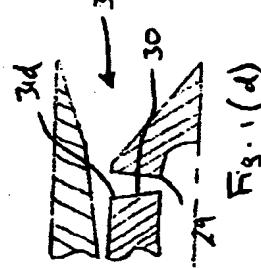


Fig. 1(d)

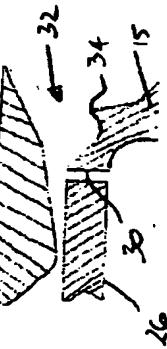


Fig. 2

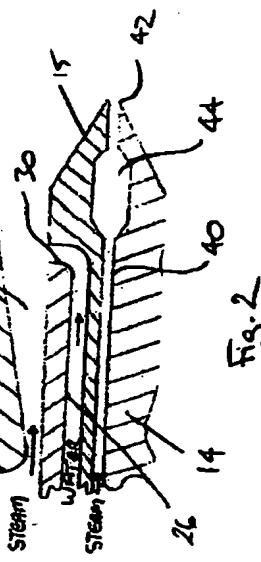
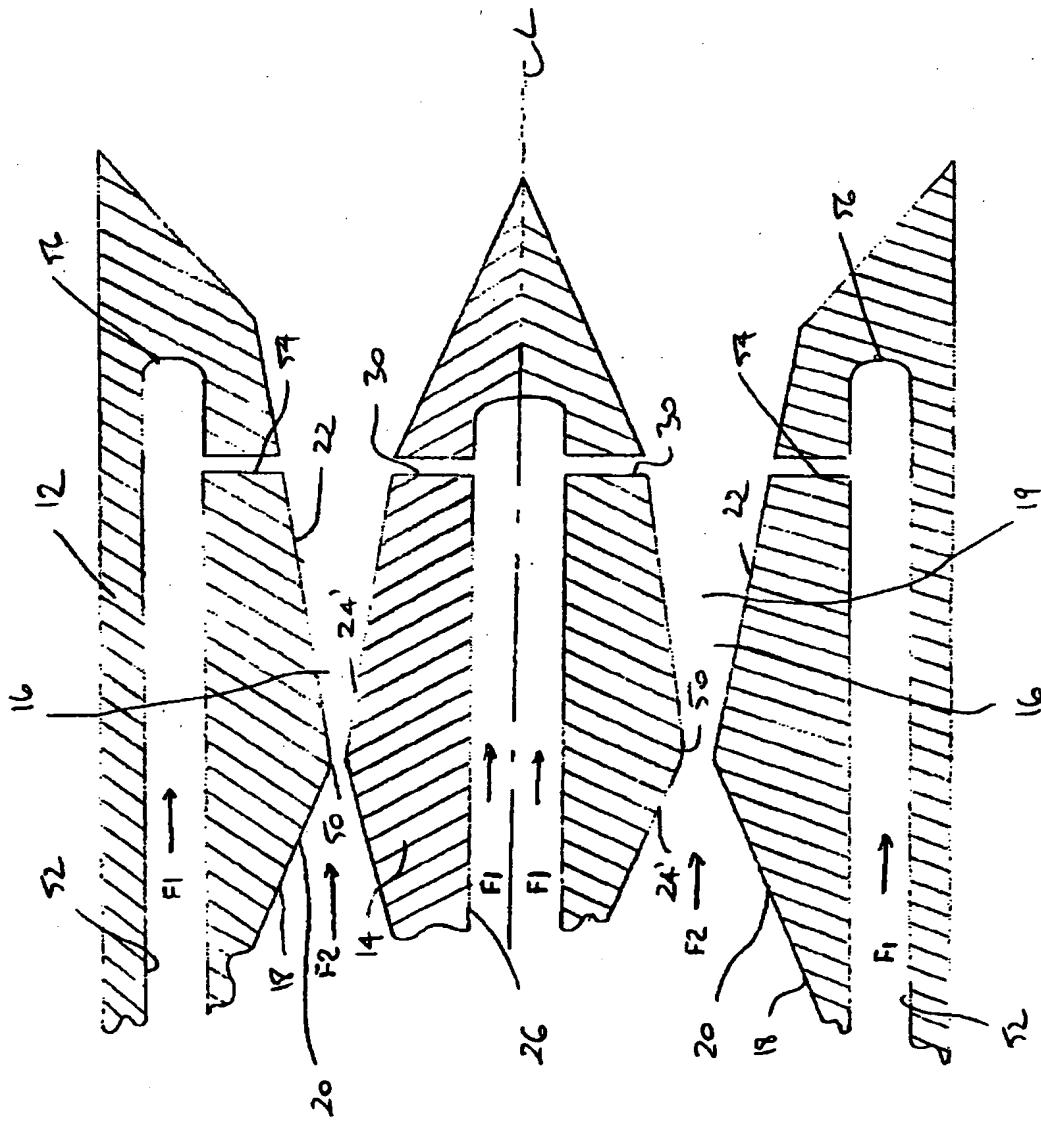
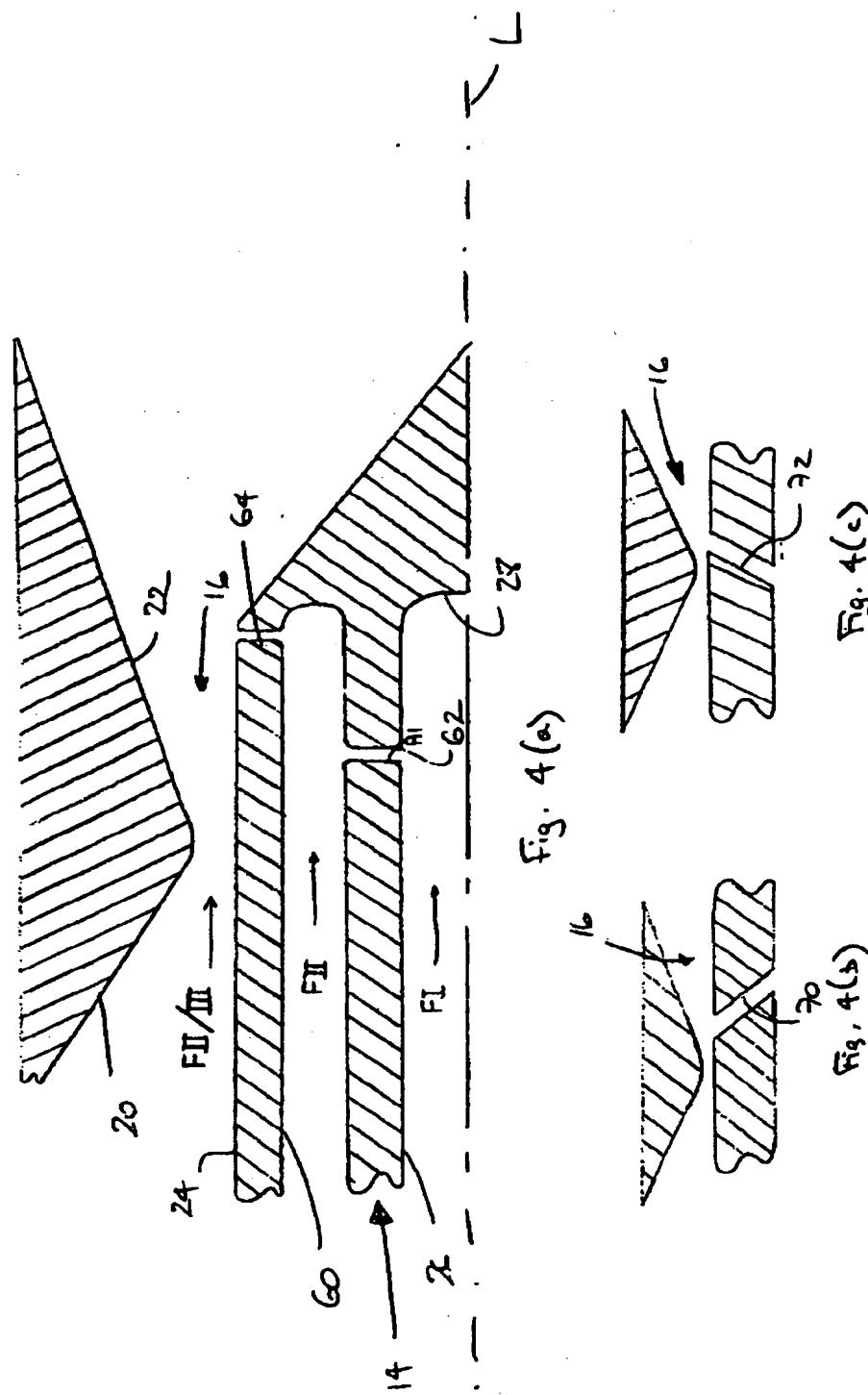


Fig. 3



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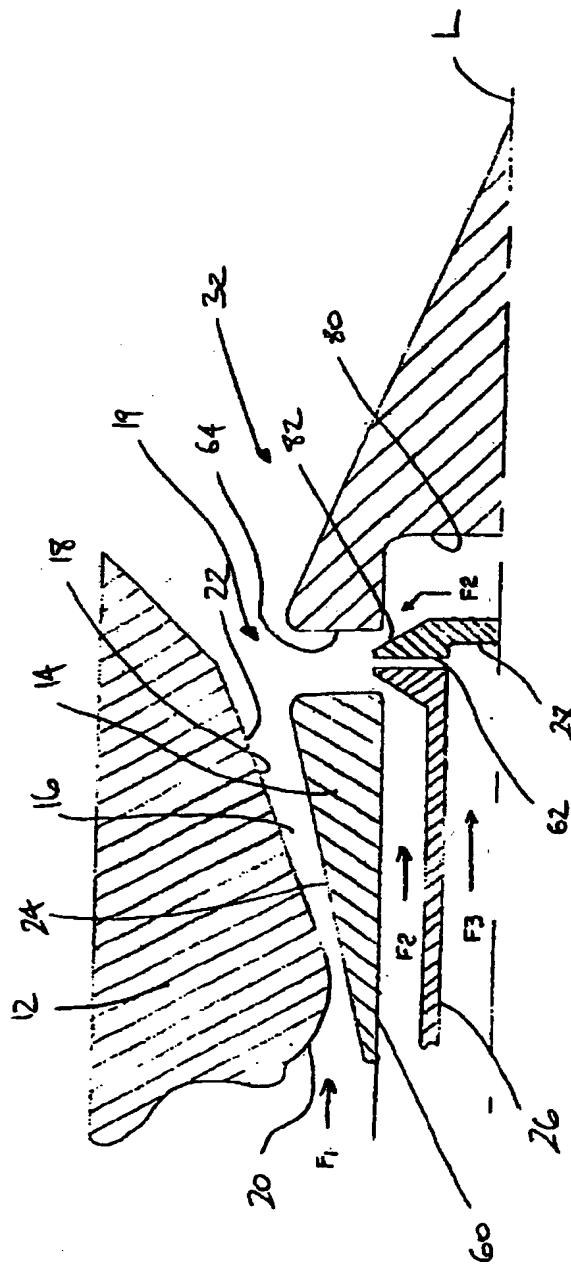


Fig. 5

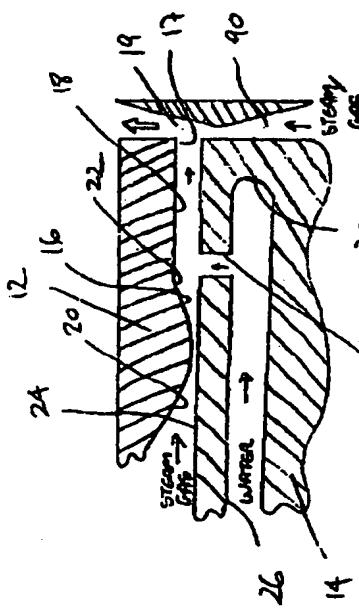


Fig. 6

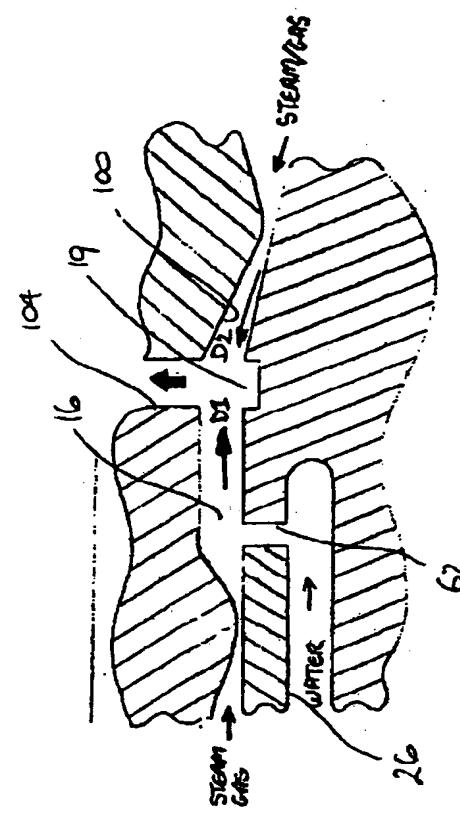


Fig. 7